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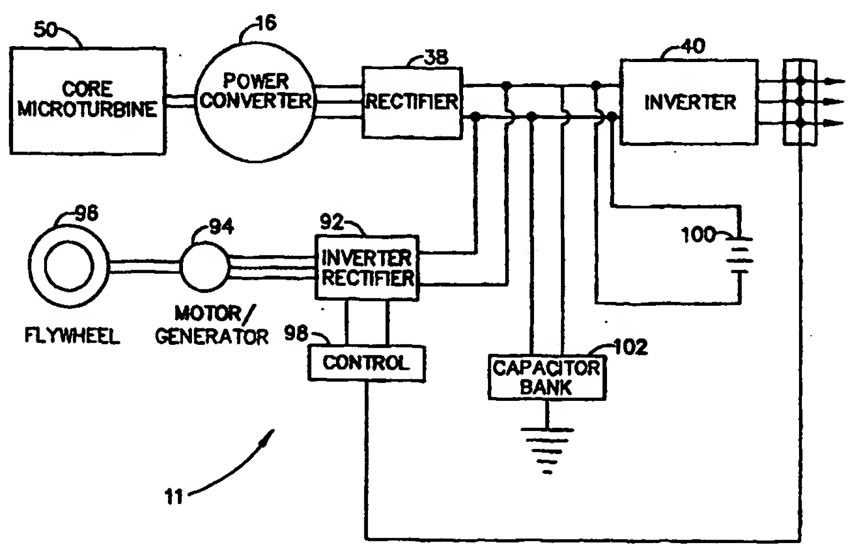

(57) Abstract

A microturbine power generation system includes an electrical generator, a turbine and a compressor intermediate the generator and the turbine. The turbine, compressor and electrical generator are secured together by a tieshaft. An energy storage reservoir is coupled to electrical generator for collecting energy when the electric generator is producing more power than demand and discharging energy when the electrical generator operating at less power than demand.

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AN UNINTERRUPTIBLE MICROTURBINE POWER GENERATING SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates generally to microturbine power generating systems. and more specifically, to an uninterruptible modular, distributed microturbine power generating system.

The United States Electric Power Research Institute (EPRI) which is the uniform research facility for domestic electric utilities, predicts that up to 40% of all new generation could be provided by distributed generators by the year 2006. In many parts of the world, the lack of electric infrastructure (transmission and distribution lines) will greatly expedite the commercialization of distributed generation technologies since central plants not only cost more per kilowatt, but also must have expensive infrastructure installed to deliver the product to the consumer.

Small, multi-fuel, modular distributed microturbine generation units could help alleviate current afternoon "brownouts" and "blackouts" prevalent in many parts of the world. A simple, single moving part concept would allow for low technical skill maintenance and low overall cost would allow for wide spread purchase in those parts of the world where capital is sparse. In addition, given the United States emphasis on electric deregulation and the world trend in this direction, consumers of electricity would have not only the right to choose the correct method of electric service but also a new cost effective choice from which to chose. U.S. Patent No. 4,754,607, which is assigned to the assignee of the present invention, discloses a microturbine power generating system suitable for cogeneration applications.

Yet before these units are commercially attractive to consumers, improvements are needed in areas such as increasing fuel-efficiency, reducing size and weight, and lowering thermal signature, noise, maintenance and cost penalties. Use of microturbine power generating systems as a primary power system in remote areas where power line electricity does not exist or is too expensive to install or where off grid application is desirable, requires a high degree of system reliability.

For instance computer systems can fail during a power outage and destroy computer data.

SUMMARY OF THE INVENTION

It is therefore desirable to provide a microturbine based power energy supply system that exhibits a high degree of reliability.

The invention can be regarded as a highly reliable microturbine power generating system including an energy storage reservoir coupled to an electric generator for collecting energy when the electric generator is producing more power than demand and discharging energy when the electric generator operating at less power than demand. The energy storage reservoir 11 can be coupled through a dc link to the rectifier and the inverter. The energy storage reservoir 11 can be coupled in parallel to with an electric generator to an output inverter for supplying power at a selected alternating frequency. In one embodiment the energy storage reservoir 11 can comprise a battery. In an alternate embodiment the energy storage reservoir 11 can comprise flywheel. In a preferred embodiment the energy storage reservoir 11 of the microturbine power generating system comprises inverter/rectifier motor/generator and flywheel coupled to the microturbine power generating system rectifier, and a control for switching the inverter/rectifier and motor/generator on demand wherein in a first power receiving mode, the inverter/rectifier acts as an inverter to accepts direct current from the rectifier and convert the direct current to alternating current of a preselected frequency to drive the motor to turn the flywheel to store energy and storage energy fly wheel and in a second power supply mode, the inverter/rectifier acts as a rectifier to accept alternating current from the flywheel driven generator rectifier and converts the alternating current to direct current for supply to the microturbine power generating system dc link.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features of the invention are set forth with particularity in the appended claims, however, invention itself, both as to organization and method of operation, together with objects and advantages thereof, may best be

understood by reference to the following description taken in conjunction with the accompanying drawings in which:

FIG. 2 is an illustration of block diagram of a microturbine power generating system including an energy storage reservoir according to the present invention;

Fig. 2 is an illustration of block diagram of a microturbine power generating system according to the present invention; and

FIG. 3 is an illustration of a cross-sectional view of the core section of the microturbine power generating system according to the present invention;

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 2, an illustration of block diagram of a as a highly reliable microturbine power generating system 10 including an energy storage reservoir 11 according to the present invention is shown. The energy storage reservoir 11 can be coupled to electric generator 16 for collecting energy when the electric generator 16 is producing more power than demand and discharging energy when the electric generator 16 operating at less power than demand. The energy storage reservoir 11 can be coupled through a dc link to the main rectifier 38 and the main inverter 40 . The energy storage reservoir 11 can be coupled in parallel with the electric generator 16 an output inverter so that the inverter can draw power from either or both sources and supplying power at a selected alternating frequency. In one embodiment the energy storage reservoir 11 can comprise a battery 100 . In an alternate embodiment the energy storage reservoir 11 can comprise flywheel 96 . In a preferred embodiment the flywheel energy storage reservoir 11 of the microturbine power generating system comprises an inverter/rectifier 92 motor/generator 94 and a flywheel 96 coupled to the microturbine power generating system rectifier 38, and a control 98 for switching the inverter/rectifier 92 and the motor/generator 94 on demand wherein in a first power receiving mode, the inverter/rectifier 92 acts as an inverter to accept direct current from the rectifier 38 and convert the direct current to alternating current of a preselected frequency to drive the motor 94 to turn the flywheel 96 to store energy as momentum in the

energy flywheel storage and in a second power supply mode, the inverter/rectifier 92 acts as a rectifier to accept alternating current from the flywheel driven generator 94 and converts the alternating current to direct current for supply to the microturbine power generating system dc link.

Control 98 can be connected to the out put of the main inverter 40 to sense and respond to load requirements.

Referring to FIG. 2, a power generating system 10 according to the present invention is illustrated. The power generating system 10 includes a compressor 12, a turbine 14 and an electrical generator 16. The electrical generator 16 is cantilevered from the compressor 16. The compressor 12, the turbine 14 and the electrical generator 16 can be rotated by a single shaft 18. Although the compressor 12, turbine 14 and electrical generator 16 can be mounted to separate shafts, the use of a common shaft 18 for rotating the compressor 12, the turbine 14 and the electrical generator 16 adds to the compactness and reliability of the power generating system 10.

The shaft 18 can be supported by self-pressurized air bearings such as foil bearings. As is shown in more detail in Fig. 3, the shaft 18 is supported by journal foil bearings 76 and 78 and thrust foil bearings 80. The foil bearings eliminate the need for a separate bearing lubrication system and reduce the occurrence of maintenance servicing.

Air entering an inlet of the compressor 12 is compressed. Compressed air leaving an outlet of the compressor 12 is circulated through cold side passages 20 in a cold side of a recuperator 22. In the recuperator 22, the compressed air absorbs heat, which enhances combustion. The heated, compressed air leaving the cold side of the recuperator 22 is supplied to a combustor 24.

Fuel is also supplied to the combustor 24. Both gaseous and liquid fuels can be used. In gaseous fuel mode, any suitable gaseous fuel can be used. Choices of fuel include diesel, flair gas, off gas, gasoline, naphtha, propane, JP-8, methane, natural gas and other man-made gases.

The flow of fuel is controlled by a flow control valve 26. The fuel is injected into the combustor 24 by an injection nozzle 28.

Inside the combustor 24 the fuel and compressed air are mixed and ignited by an igniter 27 in an exothermic reaction. In the preferred embodiment, the combustor 24 contains a suitable catalyst capable of combusting the compressed, high temperature, fuel-air mixture at the process conditions. Some known catalysts usable in the combustor 24 include platinum, palladium, as well as metal oxide catalyst with active nickel and cobalt elements.

After combustion, hot, expanding gases of the combustion are directed to an inlet nozzle 30 of the turbine 14. The inlet nozzle 30 has a fixed geometry. The hot, expanding gases resulting from the combustion is expanded through the turbine 14, thereby creating turbine power. The turbine power, in turn, drives the compressor 12 and the electrical machine 16.

Turbine exhaust gas is circulated by hot side passages 32 in a hot side of the recuperator 22. Inside the recuperator 22, heat from the turbine exhaust gas on the hot side is transferred to the compressed air on the cold side. In this manner, some heat of combustion is recuperated and used to raise the temperature of the compressed air en route to the combustor 24. After surrendering part of its heat, the combustion products exit the recuperator 22. Additional heat recovery stages could be added onto the power generating system 10.

The generator 16 can be a ring-wound, two-pole toothless (TPTL) brushless permanent magnet machine having a permanent magnet rotor 34 and stator windings 36. The turbine power generated by the rotating turbine 14 is used to rotate the rotor 34. The rotor 34 is attached to the shaft 18. When the rotor 34 is rotated by the turbine power, an alternating current is induced in the stator windings 36. Speed of the shaft 18 can be varied in accordance with external energy demands placed on the system 10. Variations in the shaft speed will produce a variation in the frequency of the alternating current (i.e., wild frequencies) generated by the electrical generator 16. Regardless of the frequency of the AC power generated by the electrical generator 16, the AC power can be rectified to DC power by a rectifier 38, and then chopped by a solid-state electronic inverter 40 to produce AC power having a fixed frequency. Accordingly,

when less power is required, the shaft speed and, therefore, the speed of the turbine 14 can be reduced without affecting the frequency of the AC output.

Moreover, reducing the shaft speed reduces the airflow because the compressor runs slower. Consequently, the turbine inlet temperature remains essentially constant, thus maintaining a high efficiency at part load.

Use of the rectifier 38 and the inverter 40 allows for a wide flexibility in determining the electric utility service to be provided by the power generating system of the present invention. Because any inverter 40 can be selected, frequency of the ac power can be selected by the consumer. If there is a direct use for ac power at wild frequencies, the rectifier 38 and inverter 40 can be eliminated. When high frequency power is used for fluorescent lights, not only does the lamp operate more efficiently, but inductor ballasts can be replaced by a capacitor ballasts. Such direct high frequency voltage used in a lighting system can result in a 25% greater efficiency. If only dc power is desired, the inverter 40 can be eliminated. The resulting direct current can be used for plating, elevator operation and incandescent lighting.

The power generating system 10 can also include a battery 46 for providing additional storage and backup power. When used in combination with the inverter 40, the combination can provide uninterruptible power for hours after generator failure.

During operation of the power generating system 10, heat is generated in the electrical generator 16 due to inefficiencies in generator design. In order to extend the life of the electrical generator 16, as well as to capture useful heat, compressor inlet air flows over the generator 16 and absorbs excess heat from the generator 16. The rectifier 38 and the inverter 40 can also be placed in the air stream. After the air has absorbed heat from the aforementioned sources, it is compressed in the compressor 12 and further pre-heated in the recuperator 22.

A controller 42 controls the shaft speed by controlling the amount of fuel flowing to the combustor 24. The controller 42 uses sensor signals generated by a sensor group 44 to determine the external demands upon the power generating system 10, as well as generate control commands for operating the system 10 at

maximum efficiency. The sensor group 44 could include sensors such as position sensors, shaft speed sensors and various temperature and pressure sensors for measuring operating temperatures and pressures in the system 10. Using the aforementioned sensors, the controller 42 controls both startup and optimal performance during steady state operation. The controller 42 can also determine the state of direct current storage in the battery 46 if supplied in the inverter 40, and adjust operations to maintain conditions of net charge, net drain, and constant charge of the battery.

A switch/starter control 48 can be provided offskid to start the power generating system 10. Rotation of the shaft 18 can be started by using the generator 16 as a motor. During startup, the switch/starter control 48 supplies an excitation current to the stator windings 34 of the electrical generator 16. Startup power is supplied by the battery 46. In the alternative, a compressed air device could be used to motor the power generating system 10.

Referring to FIG. 3, the "engine core" 50 of the power generating system 10 is shown. The compressor 12 includes an impeller 52 having a bore, a compressor scroll 54 and a diffuser channel 56. Air entering an air inlet 58 is filtered by an air filter 59 and directed to the compressor scroll 54. Air flowing out of the compressor scroll 54 is directed to the recuperator 22.

The turbine 14 includes a turbine scroll 60, a plurality of fixed nozzle vanes 62, and a boreless turbine wheel 64. Hot expanding gases leaving the combustor 24 are directed into the turbine scroll 60 and through the nozzle vanes 62, which redirect the hot expanding gas onto the turbine wheel 64. Turbine exhaust gas leaves the turbine 14 through an exhaust diffuser 66, which reduces the temperature and noise of the turbine exhaust gas.

The rotor 38 of the electrical generator 16 includes magnets 68 made of a rare earth material such as samarium cobalt. The magnets 68 are surrounded by a containment sleeve 70 made of a non-magnetic material such as Inconel 718. The stator windings 40 are housed in a generator housing 73. The rotor 38 has a bore and an optional containment sleeve (not shown) contacting a surface of the bore. Power conductors 72 extend from the stator windings 40 and terminate in a power

connector stud 74, which is secured to the generator housing 73.

The single shaft 18 is shown in FIG. 2 as a tieshaft 75, which extends through the bores in the rotor 38 and the compressor impeller 52. The tieshaft 75 is thin, having a diameter of approximately ___ or less. The bores have clearances that allow the tieshaft 75 to extend through the rotor 38 and the impeller 52. However, the tieshaft 75 does not extend through the turbine wheel 64. Instead, the tieshaft 75 is secured to the turbine wheel 64. The tieshaft 75 can be secured to the center of the turbine wheel hub by an inertia weld. Thus, the turbine wheel 64 is boreless in that it does not have a bore through which the tieshaft 75 extends. Eliminating the bore reduces stresses in the turbine wheel 64.

When clamped together by the tieshaft 18, the compressor impeller 52, the turbine wheel 64 and the rotor 38 are rotated as a single unit. Under high operating temperatures and rotational speeds, however, the impeller 52, the turbine wheel 64 and the rotor 38 tend to expand and grow apart. Flexing of the tieshaft 75 during operation also tends to separate the faces. To maintain contact between the faces of the impeller 52, the turbine wheel 64 and the rotor at high rotational speeds (80,000 rpm and above), the tieshaft 75
is preloaded. For example, a tieshaft 75 made of titanium can be preloaded in tension to about 90% of yield strength. During assembly, the tieshaft 75 is placed in tension, the impeller 52 and the rotor 38 are slid over the tieshaft 75, and a nut 77 is secured to a threaded end of the tieshaft 75. The tension as maintained as the nut 77 is turned. The tension is highest at the centers of the impeller 52 and the rotor 38. When the impeller 52 and the rotor 38 are rotated, high stresses in the outer portion of these components is countered by the stress applied by the tieshaft 75. .

The rotating unit 52, 64, 38 and 18 is supported in a radial direction by inboard and outboard foil journal bearings 76 and 78. The rotating unit 52, 64, 38 and 18 is supported in an axial direction by a foil thrust bearing 80. A base 79 provides support for a fuel inlet, the air inlet 58, the compressor 12, the turbine 14, the generator 16, the recuperator 22, the combustor 24, the rectifier 38, and the inverter 40, to enable the system 10 to exist as a packaged unit.

Various coolant ports are provided for the engine core 50. Provided are ports

82 and 84 for circulating a coolant over the stator windings 40. Also provided are ports 86 and 88 for circulating a coolant over the bearings 76, 78 and 80.

The power generating system 10 can be built in several major modules such as a rotating module, a heat exchanger module, a combustor module, and an electronics module. Each of these modules is relatively lightweight and compact. The modules can be replaced without breaking liquid lines. The use of foil bearings 52 and 54 eliminates the need for an oil-based lubrication system and, therefore, results in low maintenance of the power generating system 10. Scheduled maintenance would consist primarily of replacing the igniter 27, the filter 59 and catalyst elements in the combustor 24.

The power generating system 10 operates on a conventional recuperated Brayton cycle. The Brayton cycle can be operated on a relatively low pressure ratio (3.8) to maximize overall efficiency; since, in recuperated cycles, the lower the pressure ratio, the closer the turbine exhaust temperature is to the inlet temperature. This allows heat addition to the cycle at high temperature and, in accordance with the law of Carnot, reduces the entropic losses associated with supplying heat to the cycle. This high temperature heat addition results in an increased overall cycle efficiency. Air is compressed in a single stage radial compressor to 3.8 bars. The compressed air can be directed to the recuperator 22where the temperature of the compressed air is increased using the waste heat of the turbine exhaust gas. The temperature of the exhaust gas from the turbine is limited to about 1,300°F in order to help extend the life of the recuperator 22. For exhaust gas temperatures above 1,300°F, the recuperator 22 can be made of super alloys instead of stainless steel. The recuperator 22 can be designed for either 85% or 90% effectiveness depending on the economic needs of the customer. In the most efficient configuration, and using the 90% recuperation, the overall net cycle efficiency is 30%, yielding a high heating value heat rate of approximately 11,900 BTU/kWh on diesel.

After being heated in the recuperator 22, the compressed air is directed to the

combustor 24, where additional heat is added to raise the temperature of the compressed air to 1,650 F. A combustor 24 designed according to a conventional design can yield a Nox level of less than 25 ppm, and a combustor 24 using a catalyst can yield a Nox rate that is virtually undetectable (commercial Nox sensors are limited to a 2 to 3 ppm detection range). The high enthalpic gas is then expanded through the turbine 14. The compressor 12, the turbine 14, the generator 16, and the single shaft 18 - the only moving part in the engine core 50 - spins at high speeds of approximately 80,000 rpm or more. The resulting high frequency of around 1,200 hertz is then reduced with the inverter 38 to a grid-compatible 50 or 60 cycles. Resulting is a high power density typified by low weight (about a third of the size of a comparable diesel generator) and a small footprint (for example, approximately 3 feet by 5 feet by 6 feet high).

The high power density and low weight of the technology is made possible through the high speed components which permits large amounts of power using a minimum of material. The unit is completely self-contained in a weather proof enclosure. The power generating system 10 is "plug and play" technology, requiring little more than a supply of clean fuel, liquid or gas.

Thus disclosed is a power generating system 10 that can use multiple fuels including natural gas, diesel and JP-8. The power generating system 10 has a low thermal signature and minimal noise generation. The use of air bearings eliminates the need for an oil-based lubrication system. The electrical generation system 10 has high reliability and minimal service requirements due to single moving part design. The use of a solid-state electronic inverter allows the system 10 to provide a variable AC output. Installation is easy due to a modular and self contained design, and servicing is easy because the system 10 has one moving part and major parts that are easily accessible. The width, length and height of the engine core 50 can be adjusted to fit a wide variety of dimensional requirements.

The power generating system 10 is smaller, lighter, is more fuel-efficient and has lower thermal signature, noise, maintenance and cost penalties than comparable internal combustion engines. Therefore, due to its low initial first cost,

low installation costs, high efficiency, high reliability and simple, low cost maintenance, the electrical power generating system 10 provides lower operating and fixed costs than power generation technologies of comparable size.

Potential applications for the power generating system 10 are many and diverse. Applications include use in off-grid applications for standalone power, on-grid applications for peak shaving, load following or base load service, emergency back-up and uninterruptible power supply, prime mover applications (e.g., pump, air conditioning) and automotive hybrid vehicles. Alternatively the present invention could be configured without the electrical generator 18. Turbine power would transmitted and applied directly, as in the case of a mechanically driven refrigeration system. Therefore, it is intended that the present invention be construed according to the following claims.

What is claimed is:

1 A microturbine power generating system for producing power comprising: a turbine for converting gaseous heat energy into mechanical energy, an electric generator for converting the mechanical energy produced by the turbine into electrical energy; and a single shaft connecting the turbine and an electric generator disposed in prestressed relation to allow the electric generator to rotate in unison with the turbine and to thereby use the mechanical energy extracted by the turbine to produce electric power producing alternating electric current and energy storage reservoir coupled to the electric generator for collecting energy when the electric generator is operating and discharging energy when the electric generator operating a less than a specified demand.

2. The microturbine power generating system of claim 1 wherein microturbine power generating system includes a rectifier coupled to the electrical generator for the rectifying alternating electric current produced by the generator into dc current and wherein the energy storage reservoir is coupled through a dc link to the rectifier.

3. The microturbine power generating system of claim 1 wherein microturbine power generating system includes an inverter which is coupled to the rectifier, the inverter accepts direct current from the rectifier and converts the direct current to alternating current of a preselected frequency; and wherein the energy storage reservoir is coupled through a dc link to the rectifier and the inverter.

4. The microturbine power generating system of claim 1 wherein the energy storage reservoir is coupled in parallel to the electric generator.

5. The microturbine power generating system of claim 1 wherein the energy storage reservoir comprises a battery.

6. The microturbine power generating system of claim 1 wherein the energy

storage reservoir comprises a flywheel.

7. The microturbine power generating system of claim 1 wherein the energy storage reservoir comprises a battery and a flywheel.

8. The microturbine power generating system of claim 1 wherein the energy storage reservoir comprises inverter/rectifier motor/generator and flywheel coupled to the rectifier, and a control for switching the inverter/rectifier and motor/generator on demand wherein in a first power receiving mode, the inverter/rectifier acts as an inverter to accepts direct current from the rectifier and convert the direct current to alternating current of a preselected frequency to drive the motor to turn the flywheel to store energy and storage energy in the flywheel and a second power supply mode, the inverter/rectifier acts as a rectifier to accept alternating current from the flywheel driven generator rectifier and convert the alternating current to direct current for supply to the dc link.

9. A method of generating power from high temperature gases comprising the steps of:

expanding the high temperature gases through a turbine to produce mechanical energy;

coupling a power converted in a prestressed relation with the turbine for converting mechanical energy into power,

providing energy storage reservoir comprising inverter/rectifier motor/generator and flywheel coupled to the power converter and

storing energy in an energy storage reservoir comprising inverter/rectifier motor/generator and flywheel coupled to the power converter.

10. The method of claim 9 includes the step of rectifying power from the power converter switching the inverter/rectifier and motor/generator to a receive/storage mode when power produced is less than demand and switching the inverter/rectifier and motor/generator a second power supply mode, when power

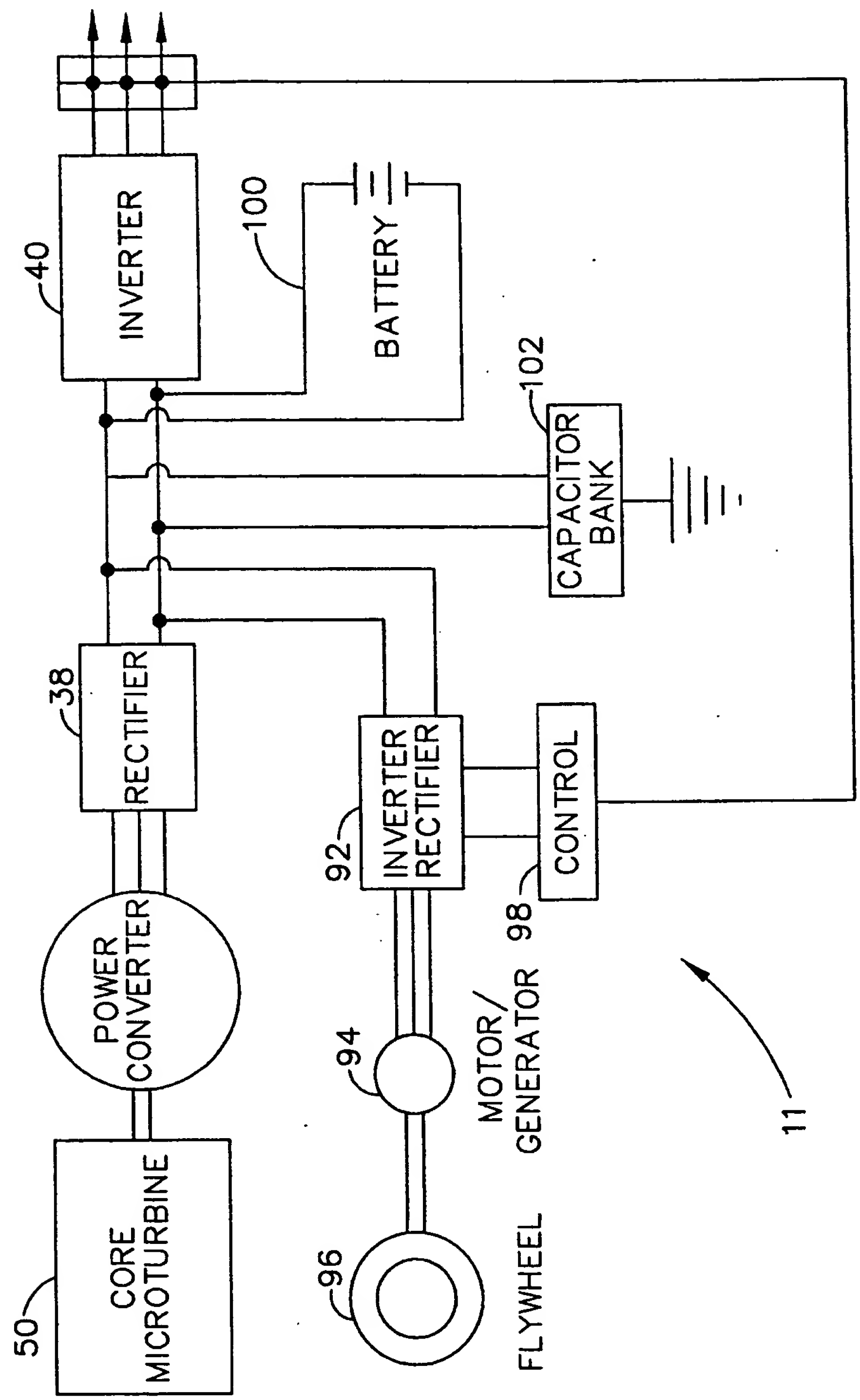
demand exceeds supply.

11 The method of claim 9 wherein the step of switching the inverter/rectifier and motor/generator to a receive/storage mode when power produced is less than demand includes the steps of switching the inverter/rectifier to acts as an inverter to accepts direct current from the rectifier and convert the direct current to alternating current of a preselected frequency to drive the motor to turn the flywheel to store energy in the energy storage flywheel.

12 The method of claim 9 wherein the step of switching the inverter/rectifier and motor/generator to a second power supply mode, when power demand exceeds supply. includes the steps of switching the inverter/rectifier to act as a rectifier to accept alternating current from the flywheel driven generator and converting the alternating current to direct current for supply to the power converter.

13. The method of claim 9 further comprising the step of

rectifying the variable frequency alternating current electrical energy from the flywheel to produce direct current electrical energy;


INVERTER
40
100
BATTERY
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CAPACITOR BANK
RECTIFIER
38
INVERTER RECTIFIER
92
CONTROL
98
POWER CONVERTER
MOTOR/ GENERATOR
94
CORE MICROTURBINE
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FLYWHEEL
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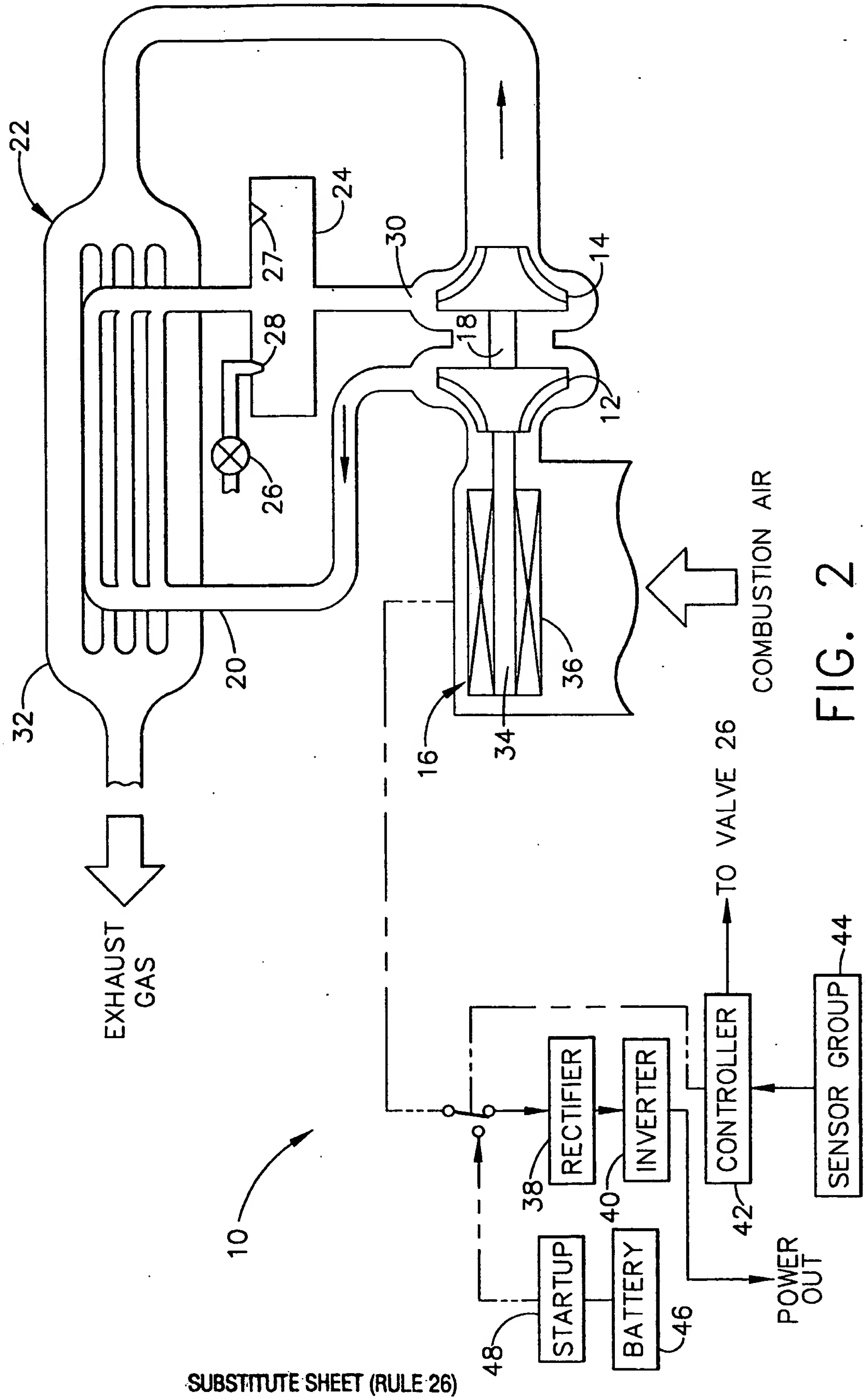
FIG. 1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COMBUSTION AIR
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FIG. 2

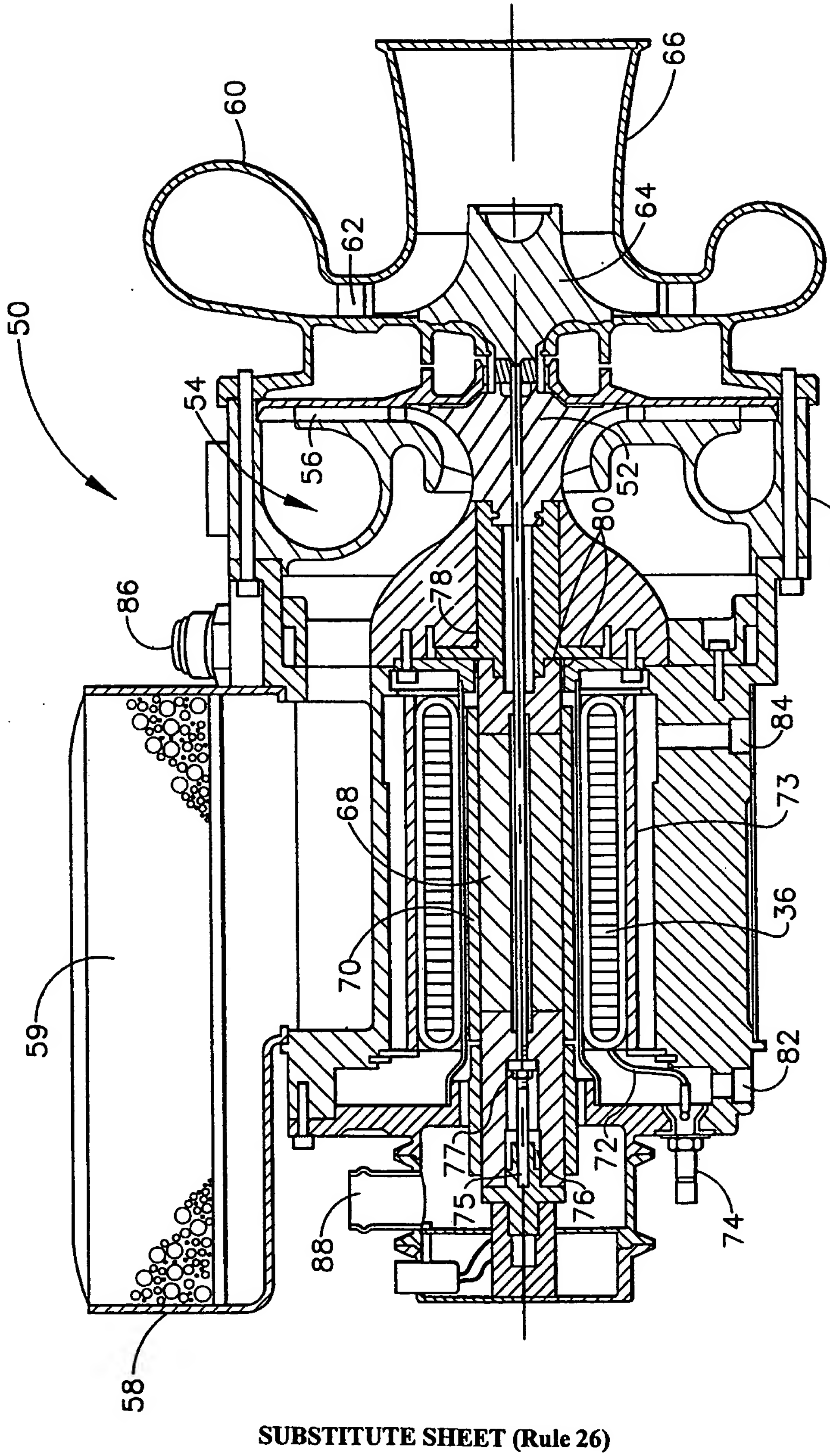
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FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/27160

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F01D15/10 F02C6/14 H02J7/32 H02J3/32 H02J9/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F01D F02C H02J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	FR 1 453 862 A (TOËSCA RENÉ A M) 21 December 1966 see the whole document ---	1-5 1-10
Y	US 4 638 173 A (MILTON RONALD I) 20 January 1987 see column 1, line 33 - line 36 see column 2, line 1 - line 5 see column 3, last paragraph - column 4, paragraph 1 ---	1-10
X	US 4 119 861 A (GOCHO CHOICHI) 10 October 1978 Use of flywheel diodes see abstract see column 5, line 8 - line 14 see figures --- -/--	1-13

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
8 April 1999	16/04/1999

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1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/27160

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	US 5 767 637 A (LANSBERRY GEOFFREY B) 16 June 1998 see figures see column 2, line 59 - column 3, line 2; figures	1-10
X	US 4 598 542 A (REYNOLDS GRAHAM A) 8 July 1986 see column 4, paragraph 2; figure 4	1-5
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A	EP 0 680 139 A (AISIN SEIKI) 2 November 1995 see page 3, line 1 - line 26; figure 1	1-13

1

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 98/27160

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